Volume 5 DECEMBER 12, 1930 Number 7

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM

OF THE

ANNUAL MEETING, CLEVELAND, OHIO

DECEMBER 30–31, 1930

IN AFFILIATION WITH SECTION B—PHYSICS—OF
THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT
OF SCIENCE

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The American Physical Society

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ANNUAL MEETING, CLEVELAND, OHIO, December 30–31, 1930

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SECTION B—PHYSICS OF

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The Thirty-second Annual Meeting (the 168th regular meeting) of the American Physical Society will be held in Cleveland, Ohio, in the Physics Laboratories of the Case School of Applied Science and Western Reserve University on Tuesday and Wednesday, December 30–31, 1930, in affiliation with Section B—Physics—of the American Association for the Advancement of Science.

General Business Session. The general business session of the American Physical Society will be held at 2 o'clock on Tuesday afternoon in the Case School Physics Lecture Room.

The Address of the Retiring Vice-President of Section B, Professor C. E. Mendenhall of the University of Wisconsin, will be delivered on Wednesday morning at the joint session with the American Physical Society in the Case School Physics Lecture Room. The subject of his address will be "Recent Developments in Photo-Electricity." At this session there will be a symposium on Acoustics. The speakers will be Dr. Harvey Fletcher, Dr. C. W. Hewlett and Dr. Paul Sabine. The Vice-President of Section B, Professor F. K. Richtmyer of Cornell University will preside at this session.

Josiah Willard Gibbs Lecture. On Tuesday afternoon at 4 o'clock Professor Edwin B. Wilson of Harvard University will deliver the Josiah Willard Gibbs Lecture.

Opening Session of the A.A.A.S. The opening session of the A.A.A.S. will be held on Monday evening, December 29th, in the Music Hall of the Public Auditorium. The address of the Retiring President of the American Association for the Advancement of Science, Professor Robert A. Millikan, will be delivered at that time. His topic is "Atomic Disintegration and Atomic Synthesis."

Other Sessions of the A.A.A.S. The annual Sigma Xi lecture will be given Tuesday evening, December 30th. Dr. C. E. K. Mees of the Eastman Kodak Company will speak on "The Science of Photography." This will be at 8:30 o'clock in the John Hay High School Auditorium.

Dinner. The Society of Sigma Xi has extended an invitation to the American Physical Society to join with them at dinner on Tuesday evening at 6:30 P.M. at the Cleveland Club. Tickets for the dinner will be on sale at the Sigma Xi desk at Registration Headquarters beginning at 9 A.M. Monday, December 29th and the sale will continue up to Tuesday noon, December 30th. The price of the dinner is $2.50. After the dinner the Societies will attend the Sigma Xi lecture. Seats in the lecture hall will be reserved for those in attendance at the dinner.

CALENDAR

Monday evening, Dec. 29:

8:15 o'clock—Opening session of the A.A.A.S. Address by Dr. Robert A. Millikan.

Tuesday morning, Dec. 30:

10:00 o'clock—Papers 1–11, Case School Physics Lab. Papers 12–23, Western Reserve Physics Lab.

Tuesday afternoon, Dec. 30:

2:00 o'clock—Annual Business Session, Case School Physics Lecture Room.

2:30 o'clock—Papers 24–33, Case School. Papers 34–43, Western Reserve.

4:00 o'clock—Willard Gibbs Lecture by Professor Edwin B. Wilson.

Tuesday evening, Dec. 30:

6:30 o'clock—Joint dinner with Sigma Xi at the Cleveland Club.

8:30 o'clock—Sigma Xi Lecture by Dr. C. E. K. Mees at John Hay High School.

Wednesday morning, Dec. 31:

10:00 o'clock—Case School Physics Laboratory. Joint session with Section B. Vice-Presidential address by Professor C. E. Mendenhall. Followed by a Symposium on Acoustics. Invited Papers 44–46.

Wednesday afternoon, Dec. 31:

2:00 o'clock—Papers 47–58, Case School. Papers 59–70, Western Reserve.

The supplementary papers Nos. 71–76 may be called for at the end of any regular session in the Case School Physics Lecture Room.

Titles and abstracts of the papers to be presented before the Physical Society are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the *Physical Review*. Authors should send corrections to the Editor of the *Physical Review* at The University of Minnesota, Minneapolis, Minnesota.

GENERAL INFORMATION

For further information in regard to sessions, meetings, receptions, exhibitions, excursions, etc., see the General Program of the A.A.A.S. which will be available at the registration offices. See also the Preliminary Announcement of the A.A.A.S., printed in Current issues of Science.

Headquarters for Physicists. Hotel Statler, Euclid Ave. at East 12th Street, has been selected for hotel headquarters for the American Physical Society, at the Cleveland meeting. Members are urged to make their reservations at once (writing directly to the hotel).

The rates at the Hotel Statler are: $3.50 up, with bath.

Members desiring other accommodations may apply to Auditorium Hotel or Hotel Olmsted where the rates are $2.00 up.

Railroad Rates. Any person attending the meetings of the A.A.A.S. or its Affiliated Societies, may take advantage of the reduced railroad rates, on the usual certificate plan. The traveler should purchase a one-way, full-fare, through ticket to Cleveland, and secure at the same time from the agent a "certificate for the Cleveland convention of the American Association for the advancement of Science and Associated Societies." This certificate must be validated at the registration rooms of the A.A.A.S. at the time of the meeting; it will then entitle the owner to a return ticket by the same route without stop-over at half the full fare, within the usual time limits.

Registration. Members should register immediately upon arrival at the registration offices of the A.A.A.S. It will be necessary to call a day or two later for the validated railway certificate.

A registration fee of one dollar will be charged members of the A.A.A.S. who pay their dues for 1930–31. All others pay two dollars. Registration entitles the person registering to a copy of the General Program and its supplements, to the official badge, to all the general privileges of the meeting and to the validation of one railway certificate.

Membership in the A.A.A.S. Members of affiliated societies are given the privilege of joining the Association at this meeting without payment of the regular entrance fee. Members of any affiliated society simply pay the first annual dues ($5) when they join the A.A.A.S. This payment entitles them to membership for the fiscal year from October 1 to September 30, including a subscription to the official journal, *Science* (or the *Scientific Monthly*, if they prefer), for the calendar year beginning in the fiscal year just defined.

GENERAL RULES RELATING TO PAPERS

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Other meetings for the current season are as follows:

169. February 26–28, 1931. New York City. Joint meeting with the Optical Society of America.

170. May 1–2, 1931. Washington.

171. June 15–20, 1931. Pacific Coast meeting, Pasadena.

172. June 18–20, 1931. Summer meeting, Princeton.

W. L. SEVERINGHAUS, *Secretary*,
Columbia University, New York City.

December 12, 1930.

PROGRAM

TUESDAY MORNING AT 10 O'CLOCK

Case School Physics Lecture Room

1. Mass absorption coefficient of the *K* shell according to the Dirac relativistic equation. LOUIS C. ROESS, *Cornell University.* (*Introduced by E. H. Kennard.*)—Taking as model an atom containing two non-interacting electrons and a fixed nucleus with charge Ze, the mass absorption coefficient is calculated using the proper functions of the Dirac relativistic equation. Z is determined so as to make the lowest energy level agree with the experimental value determined from the K absorption edge. The numerical calculation presented difficulty because of lack of tables of complex gamma functions. The relativistic coefficient is found to be from 0% to 40% smaller than the non-relativistic coefficient calculated by Nishina and Rabi, the greatest difference occurring for the heavy elements and short wave-lengths; it agrees slightly worse with experiment than the non-relativistic coefficient. The difference between theory and experiment is least for the heavy atoms, as would be expected, since for the heavy atoms (large Z) the neglected electronic interaction-field is small in comparison with the nuclear field. The variation of the relativistic coefficient with wave-length is complicated, but in the range $\frac{1}{2}\lambda_k$ to λ_k (λ_k = wave-length of K absorption edge) it is more nearly linear with λ^3 than the non-relativistic coefficient. The importance of using the relativistic equation for heavy atoms and short x-ray wave-lengths is emphasized by these results, which also show that the model chosen is too approximate, even for the heavy elements.

2. Nature of magnetic doublet in para-azoxyanisol at 122° and 128°C as determined by x-ray diffraction. G. W. STEWART, *University of Iowa.*—A difference of opinion exists as to whether the magnetic moment of para-azoxyanisol in its liquid crystalline form, 117°C to 134°C, is an induced one or is independent of the field. A magnetic field is applied perpendicular to the axis of rotation of the spectrometer and to the x-ray beam passing through the sample. The effect of the field in the diffraction halo is studied quantatively. Boltzman's distribution law is assumed. The data are in agreement with the computations assuming the magnetic moment to be not polarized but permanent and to possess a value of 2.65×10^4 Bohr magnetons, in agreement with the results of Kast. This suggests, but does not make certain, that a group of that number of molecules gives rise to the magnetic moment. The diffraction of x-rays at temperatures above 134° shows the disappearance of the magnetic moment, but a retention of groups otherwise similar to those just suggested. The groups causing optical anisotropy are larger and not regular enough throughout to produce coherent x-ray diffraction. These large groups are easily affected by the stirring of the liquid. The time required for orientation is easily shown by the application of an alternating magnetic field. The experiment shows the value of the direct x-ray investigation.

3. The utilization of intensity data from Laue photographs. MAURICE L. HUGGINS, *Stanford University.*—The measurement of Laue photograph intensities and the calculation of structure factors from them are discussed. Methods of correcting for differences (in intensity of the incident radiation, in absorption and in photographic effect) dependent on the wave-length, for differences (in size of the spot, in absorption and in the background of scattered radiation) dependent on the reflection angle, and for absorption (including primary and secondary extinction) dependent on the nature of the crystal, are considered and the results of preliminary measurements and calculations presented.

4. The characteristic x-ray absorption of molecules in the vapor state. J. D. HANAWALT, *National Research Fellow, University of Michigan.*—The purpose of the work here described is to provide a better understanding of the secondary absorption discontinuities which appear on the short wave-length side of the K and of the L x-ray absorption edges of many substances.

The interpretation of the secondary discontinuities has been especially difficult because the absorption has not been obtained for atoms in the isolated state. In the present work the characteristic x-ray absorption spectra of numerous polyatomic and monatomic molecules in the vapor state has been photographed with a dispersion of about 5 XU/mm, and the results compared with the absorption spectra exhibited by the same substances in the solid state. The monatomic substances investigated are superheated Hg vapor, superheated Zn vapor and Krypton. The polyatomic substances are the vapors of As_4, $AsCl_3$, As_2O_3, Br_2, NaBr, $HgCl_2$, Se_8, SeO_2. It is found that none of the monatomic molecules show any absorption discontinuities at distances from the main edge greater than the ionization potential of the atom. The polyatomic molecules, however, show secondary absorptions in the vapor state differing only in minor details from the absorption of the same substance in the solid state. This makes it appear that the secondary discontinuities are only observed for atoms which are bound to other atoms. If the discontinuities are to be attributed to simultaneous jumps of two or more electrons within the atom, one has yet to understand why they do not occur in isolated atoms.

5. X-ray absorption coefficients of the light elements and their relations to the various absorption formulae. S. J. M. ALLEN, *University of Cincinnati.*—The x-ray absorption coefficients of the elements have been measured with greater precision and care at $\lambda = 1.539$A and 1.934A with especial reference to the low atomic weight elements, O, C, B, Be, Li, H. It was found necessary for these to have a complete chemical analysis carried out and corrections made by the additive law to ensure resultant values of μ/ρ, for which some degree of certainty could be stated. An impurity of iron of less than 0.1 percent at $\lambda 1.539$ can have a marked effect. The values of μ/ρ, so far obtained, are compared to those predicted by the various formulae. A new formula developed by the author which was found to hold exceedingly well down to neon indicated irregularities below that point, C, N, and O certainly falling below the formula and Be and Li probably above. The same was generally true with the Z^4/A (Owens) law. The value of μ/ρ for Li at $\lambda 1.539$ extended by the λ^3 law to $\lambda 0.71$ (Kα of Mo) gives values much less than those previously reported (Hewlett, Mazumdar) at this wave-length.

6. The upper atomic number limit of the satellites of the x-ray line $L\beta_2$. ROBERT D. RICHTMYER, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—Five satellites of the line $L\beta_2$ have previously been reported for the elements in the atomic number range 40 to 51. An attempt was made to extend this range to higher atomic numbers, and to determine whether there is a limit in the atomic number scale beyond which the satellites do not exist. A Siegbahn vacuum spectrometer was used, the only departure from the usual photographic method of x-ray spectrometry being the comparitively high voltage on the x-ray tube. The satellite $L\beta_2(a)$ was observed and measured for elements 50, 51, 52, 53, 56, 58, and 60; and two others, $L\beta_2'$ and $L\beta_2''$, only as far as element 53. For elements above Xe (54), the diagram lines (Siegbahn) $L\beta_7$, $L\beta_9$, and $L\beta_{10}$ shift their positions in the spectrum relative to $L\beta_2$ in such a way that they occupy the region just where one would expect to find the satellites $L\beta_2'$ and $L\beta_2''$, making observations difficult. The plates seem to show, however, that these satellites fade out and disappear with atomic number 53. The satellites $L\beta_2(b)$ and $L\beta_2(c)$ are not found above number 50. Throughout these extensions of their ranges the satellites, where found, obey the law that $(\Delta\nu/R)^{1/2}$ is a linear function of atomic number.

7. Upper atomic number limit of the satellites of the x-ray line $L\alpha_1$. E. RAMBERG, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—The satellites of $K\alpha_1$, namely $K\alpha_2$ and $K\alpha_4$, decrease in intensity rapidly with increasing atomic number above Cu(29) and have not been reported above As(33). Their disappearance seems to coincide, roughly, with the completion of Period IV of Bohr's periodic table. Similarly the satellites of $L\alpha$, although strong at Cd(48), fade out very rapidly as the end of (Bohr's) Period V is approached. The present paper is concerned with an attempt to map, by very long exposures, these $L\alpha$ satellites in the atomic number range Sn(50) to Ce(58). There is no certain evidence of their existence above Xe(54). From Sn(50) to I(53) they fade out into a very faint, diffuse band which shows very little evidence of structure, and in which therefore the identification of the lines and their wavelength measurements are difficult. The bearing of these data on the problem of the origin of satellites is discussed.

8. Are the wave-lengths of x-ray satellites affected by chemical combination? F. K. RICHTMYER, *Cornell University.*—The "two-electron jump" theory of the origin of satellites, proposed by the author, postulates that one of the jumps should be between outer electron shells and should therefore be somewhat affected by chemical combination. That is, the difference in wave-length $\Delta\lambda$ between a satellite and its parent line should depend on the chemical state of the emitting atom. The present paper describes an attempt to detect such a shift in wave-length for the $K\alpha$ satellites of Si(14), S(16), Ca(20), Ti(22) and the $L\beta_2$ satellites of Ag(47). Except in the case of Si(14) the data are inconclusive because of the possible reduction or oxidation of the element in the target and the resulting well-known change in wave-length of the parent lines. Measurements on Si(14) were less ambiguous. Comparing the $K\alpha_{3,4}$ satellites of metallic silicon with those from Na_2SiO_3, the $\Delta\lambda$ for the silicate is 3.9 percent greater in the case of $K\alpha_3$, and 2.8 percent greater in the case of $K\alpha_4$ than for metallic silicon. These data are in substantial agreement with those of Bäcklin (Zeits. f. Physik **38,** 215, 1926). It will apparently be necessary to study fluorescence spectra to avoid spurious effects of chemical reduction in the target.

9. Interpretation of x-ray satellite lines. R. M. LANGER, *Massachusetts Institute of Technology.*—Quantum mechanical calculations show that double electron jumps involving two electrons in different shells would give lines too faint to account for observed x-ray satellites. A theory can be given for single electron jumps in doubly ionized atoms which would give lines of much greater intensity and which would be compatible with the experimental results of Richtmyer and Taylor, and DuMond and Hoyt. According to this theory the $K\alpha$ satellites α', α_4, α_3, α_5, α_6 of the elements from Na on, are due to the transitions

$$(1s)(2s)(2p)^6\ {}^1S - (1s)^2(2s)(2p)^5\ {}^1P \ldots\ (\alpha')$$
$$(1s)(2s)(2p)^6\ {}^3S - (1s)^2(2s)(2p)^5\ {}^3P \ldots\ (\alpha_4)$$
$$(1s)(2s)^2(2p)^5\ {}^3P - (1s)^2(2s)^2(2p)^4\ {}^3P \ldots\ (\alpha_3)$$
$$(1s)(2s)^2(2p)^5\ {}^1P - (1s)^2(2s)^2(2p)^4\ {}^1S \ldots\ (\alpha_5)$$
$$(1s)(2s)^2(2p)^5\ {}^1P - (1s)^2(2s)^2(2p)^4\ {}^1D \ldots\ (\alpha_6).$$

There are five transitions to be expected and five are observed. Moreover the relative intensities come out in agreement with experiment. Accurate calculations of the separations between lines cannot at present be made because exact wave functions are not known. The best available wave functions give separations about 50 percent off. The present theory can be extended to explain the structure of absorption edges and the shift of absorption edge with valence.

10. A check on the lattice constants and axial ratios of stibnite. JOHN G. ALBRIGHT, *Case School of Applied Science.*—Dana (Textbook of Mineralogy) classifies stibnite as orthorhombic with axial ratios 0.9926:1:1.0179. Gottfried (Zeitschrift für Kristallographie **65,** 427–434, 1927) gives the axial ratios as 0.992:1:0.338 and the lattice constants as $a=11.39$A, $b=11.48$A, $c=3.89$A, making the value for the unit cell along the c axis about one third of that indicated by Dana's values. In view of Dana's reputation for accuracy it was thought desirable to check the determinations of Gottfried. X-ray diffraction and reflection photographs give values for the lattice constants of $a=11.29$A, $b=11.45$A, $c=3.87$A, making the axial ratios 0.986:1:0.339, which agree very well with the values given by Gottfried.

11. X-ray analysis of cold rolling and recrystallization in steel. C. NUSBAUM, *Case School of Applied Science.*—A careful and extensive study, by means of Laue photographs, has been made of the effect of cold rolling on low carbon steel and the subsequent heat treatment necessary for its complete removal. The changes due to increasing degrees of cold rolling may be considered as taking place in three stages (1) introduction of internal stresses as indicated by radial asterism, (2) the fragmentation of the individual crystals, and (3) the increasing degree of preferred orientation of the crystal fragments. The necessary temperature in the subsequent heat treatment for the complete removal of the effect of cold rolling is a function of the degree of the cold work. However, recrystallization is necessary for the complete removal of preferred orientation.

TUESDAY MORNING AT 10 O'CLOCK

Western Reserve Physics Lecture Room

12. The "spread" as a measure of deviation in physical measurements. ELLIOT Q. ADAMS, *Lamp Development Laboratory, Nela Park.*—In order to compare results of incandescent lamp tests expressed in terms of the spread (maximum difference) observed in sets of various numbers of lamps, it was necessary to calculate factors to convert these results to a comparable basis. The average deviation of a single observation was chosen as the basis of comparison. Assuming a Gaussian distribution of errors, the factors have been calculated by mathematically approximate methods, and may be expressed by the semi-empirical formula: Spread/(av. deviation) $=f(n)=(5.304-2.11/(0.47+\lg n))(\lg n)^{1/2}$ with an error not exceeding 0.01 in the factor. This error is negligible in comparison with the unavoidable error in determining by any method the average deviation in a set of fewer than 10^6 observations, i.e., in practically all physical measurements. While it may be shown mathematically that the average deviation so computed is less precise than that computed from the sum of the residuals, or *a fortiori* of their squares, the difference seldom exceeds the probable error of the more refined measures. The labor of computation is so much less than that of the more precise methods that an expression of the internal consistency of *all* results of physical measurements may reasonably be required.

13. The wave-mechanical theory of radiation. E. H. KENNARD, *Cornell University.*—A complete theory can easily be developed in terms of traveling plane waves instead of standing oscillations; such a form should be especially useful in dealing with phenomena which like the Compton effect involve motion. Replacing the usual Fourier integral by a series we write for the classical vector-potential of the radiation field, $A=\Sigma(i)(a_i I_i' \cos\theta_i + a_i'' I_i'' \sin\theta_i)\,\Delta\nu\Delta\omega$ where $\theta_i=2\pi\nu_i(t-gx_i)$, $c=1/g$ being the speed of light, x_i distance along the ray I_i' and I_i'' two perpendicular unit vectors and $\Delta\omega$ an element of solid angle. As coordinates and momenta we take $Q=\beta_1 a' \cos 2\pi\nu t$, $P=\beta_1 a' \sin 2\pi\nu t$, and $Q=\beta_1 a'' \sin 2\pi\nu t$, $P=-\beta_1 a'' \cos 2\pi\nu t$, $\beta_1{}^2=c\Delta\nu\Delta\omega/2\nu$; the energy is then $W=\Sigma(\sigma)\pi\nu_\sigma(Q_\sigma{}^2+P_\sigma{}^2)$, and $\boldsymbol{A}=\Sigma\boldsymbol{A}_\sigma=\Sigma\beta_\sigma I_\sigma(Q_\sigma\cos\theta_\sigma+P_\sigma\sin\theta_\sigma)$ where $\theta_\sigma=2\pi g\nu_\sigma x_\sigma$, $\beta=2\nu\beta_1/c$. We now replace P_σ by $h/2\pi i\partial/\partial Q_\sigma$ and form the Schrödinger time equation, adding in the Hamiltonian for a non-relativistic free electron simply $1/2m(\nabla-e/c\Sigma\boldsymbol{A}_\sigma)^2$. The motion of a packet is easily followed; formulas almost classical in form are obtained for its centroid, with the operators $-\Sigma\partial A_\sigma/\partial x_\sigma$ and $\Sigma\nabla\times\Sigma\boldsymbol{A}_\sigma$ acting as electric and magnetic field-strengths. The acceleration vanishes when the field is in its normal or any other pure quantum state, showing that the "zero-point" infinite energy does not imply the existence of a physical electromagnetic field.

14. On the mechanism of light absorbtion in solid bodies. J. FRENKEL, *Visiting professor from Leningrad, University of Minnesota. (Introduced by H. A. Erikson.)*—Starting from the analogy between a crystal and a molecule, it is shown that the electronic excitation, forming the first step in the process of light absorbtion, is not confined to a particular atom, but is diluted between all of them in the form of "excitation waves," similar to sound waves which are used to describe the heat motion in the same crystal. Owing to the interaction between the atoms the excitation state is split up into substates whose number is equal to the number of atoms n (excitation multiplet). By superposing several excitation waves "excitation packets" can be constructed representing the travelling of the excitation state from one atom to another. To each excitation (sub.) state there corresponds a definite crystal structure (lattice constant, vibration frequencies) slightly different from that of the normal one, and giving rise to slightly different vibrational states. This influence of the excitation on the vibrational states provides an indirect coupling between them, which allows the excitation energy to be shared between a few hundred heat-oscillators with practically no direct coupling (nor anharmonicity) in a radiationless transition which forms the second state of the process of light absorbtion.

15. Interchange of translation, vibration, and rotation energy. CLARENCE ZENER, *Harvard University.*—A modification of the Born collision method is used to calculate the effective cross-sections of inelastic collisions of the first and second kind between atoms and molecules. The unperturbed Hamiltonian is taken to be the exact Hamiltonian averaged over the internal

coordinates of the molecule. The internal motions of the molecule is treated as the perturbation that results in a transfer of energy. The sharpness of the collisions is approximately obtained from the mean ionization potentials of the two colliding systems. The small probability of transfer of vibrational and translational energy arises from the duration of the collision being greater than the time of oscillation. In general, the effective cross-section for a collision of the second kind is comparable to the kinetic theory cross-section only when a frequency of the molecule is comparable to a frequency associated with the combined system of molecule and atom.

16. Orbital valency. JAMES H. BARTLETT, JR. *University of Illinois.*—The problem of interaction of two identical atoms, each with one p valence electron, has been investigated. The total system has originally a twelve-fold degeneracy, and a first order perturbation calculation is made, using a method analogous to that of Kemble and Zener for the excited states of the hydrogen molecule. This enables one to give an estimate of the relative positions of the resulting molecular states as a function of the internuclear distance. A simple atomic wave function similar to those employed by Zener (with no radial nodes) has been used in the present work to facilitate the calculations. Complete potential energy curves have now been obtained, and agree in general with the results reported in a letter to the Physical Review **36,** 1096 (1930). The lowest state is found to be a $^1\Sigma$ state, the $^1\Delta$ state is repulsive, and the other states are mostly attractive.

17. Directed valence in polyatomic molecules. J. C. SLATER, *Massachusetts Institute of Technology.*—By means of wave mechanics one can draw conclusions regarding valence in polyatomic molecules, finding in particular that the different shared electron bonds from a single atom tend to be at definite angles to each other. The two bonds in atoms like oxygen, and the three in nitrogen, tend to be mutually perpendicular, while in carbon a tetrahedral structure is indicated. These conclusions in the first two cases rest on the nature of the wave function for a p electron: the three types of p electron may be considered to have densities large along three mutually perpendicular directions. With carbon, one must combine these three with an s electron to produce tetrahedral valences. The conclusions can be supported by a wide range of experimental facts, from the structure of simple inorganic molecules, metals, and organic compounds.

18. Polarizabilities and intra-atomic energies of hydrogen and helium. JOHN G. KIRKWOOD, *Massachusetts Institute of Technology. (Introduced by J. C. Slater.)*—A method of calculating the polarizabilities and intra-atomic energies has been developed. An approximate separation of variables in the original wave equation is effected. From the approximate wave function which is obtained, a more exact one is constructed with the use of the variation principle. The polarizability and energy of two atoms at large distances have been calculated for hydrogen and helium.

19. On the Michelson-Morley-Miller experiment. N. GALLI-SHOHAT, *Mount Holyoke College.*—At the meeting of the American Physical Society held in Washington in April, 1930, it was suggested by the writer that Professor Miller's effect can be explained by means of the effect observed by Esclangon. This further enables us to explain why Professor Michelson in the last repetition of his experiment did not observe any effect. In fact, the displacement of the fringes due to the effect of Esclangon (rotation of the whole interference pattern) depends only upon the orientation relative to the motion of the solar system of that part of the path of light in the interferometer, which goes from the last reflection directly into the eye of the observer. In the arrangement of apparatus used by Professor Michelson, this path was made stationary, being directed *along the axis of rotation.* Thus, the revolution of the interferometer around this axis *could not change* the orientation of this path in space; hence, *no effect can be expected.* While in his first arrangement, which was used also by Professor Miller, this path lies *in the plane* of the interferometer, hence, a change due to revolution and a displacement of the fringes.

20. Change in mass-weight ratio. PETER I. WOLD AND EARLE M. BIGSBEE, *Union College.*—The late Charles F. Brush carried on experiments which led him to conclude that the weight

of a metal may change when strained, giving a change in the ratio of mass to weight. His experimental technique seemed to preclude the obvious sources of errors which might be urged as explanation of his results. The matter is of sufficient importance to our theories of gravitation to justify checking and at his request weighings were made on certain alloys prepared by him. The procedure was practically the same as described in his paper in Proceedings of the American Philosophical Society (Vol. 63, 1925, p. 36). Weighings taken on various specimens showed losses in weight when the specimen was compressed and a nearly complete recovery when the stress was removed. The changes were substantially in excess of balance errors. The losses were less than found by Brush and he considered this as due to annealing during the time between the preparation of the sample and its weighing. The shorter this time the larger were the observed effects. In the last sample studied, where elapsed time was shortest, the losses amounted to one part in 130,000. The work may be considered as confirming that of Brush. The suggestion that the effects are due to changes in the amount of adsorbed gases does not appear to be a sufficient explanation.

21. Properties of single crystal magnesium. P. W. BRIDGMAN, *Harvard University.*—Pure magnesium, which I owe to the Aluminum Company of America, was prepared in single crystal form by slowly lowering out of a vacuum furnace iron molds filled with the melted metal. The crystal structure of magnesium is known to correspond to the close packed hexagonal arrangement of spheres. It is therefore to be expected that the properties will not vary greatly with direction. This turns out to be true for the compressibility, for which was found:

Parallel to the axis, at $30°-\Delta l/l_0 = 9.842\times10^{-7}p-6.51\times10^{-12}p^2$
at $75°-\Delta l/l_0 = 10.154\times10^{-7}p-7.78\times10^{-12}p^2$.
Perpendicular to the axis, at $30°-\Delta l/l_0 = 9.845\times10^{-7}p-9.19\times10^{-12}p^2$
at $75°-\Delta l/l_0 = 9.659\times10^{-7}p-6.95\times10^{-12}p^2$.

Pressure is expressed in kg/cm², and the pressure range is 12000.

The electrical resistance, however, does not satisfy expectations. At 22°.5 the specific resistance is 3.89×10^{-6} parallel to the axis, and 4.60×10^{-6} perpendicular to it. Not only does the resistance vary materially with direction, but in almost all other non-cubic metals the resistance is greater parallel to the axis. The average pressure coefficient to 12000 was found to be 4.35×10^{-6} parallel to the axis, and 4.62×10^{-6} perpendicular to it. The temperature coefficient of resistance at atmospheric pressure between 0° and 100° was 0.00523 and 0.00428 respectively.

22. Transverse heat effect in single crystal bismuth plates. H. P. STABLER, *Harvard University.*—The dependence of the transverse heat on the orientation of the crystallographic axis has been studied in single crystal bismuth. The metal was of three different varieties (of which one was specially prepared electrolytic bismuth) all having high temperature coefficients of resistance and giving identical results. The crystals were grown by a modification of Kapitza's method in the form of uniform rectangular plates, about 15×2.2 mm cross-section, and perfect over a length of from 4 to 16 cm. Measurements made on twenty-eight plates covering the entire range of orientation show clearly that the Thomson symmetry relation for the tranverse heat, $[T(\theta)=(P_\parallel-P_\perp)\sin\theta\cos\theta]$, is not satisfied. The ratio $(T(\theta)/\sin\theta\cos\theta)$ plotted against $\sin\theta\cos\theta$, instead of being constant, varies in a roughly sinusoidal manner, with the extremes at 15° and 75° differing by $24\%\pm5$. These values are 14.2 and 18.0×10^{-3} watts respectively, and at 45°, 15.9. Bridgman, Boydston, and Fagan and Collins have shown that the longitudinal Peltier effect also, in bismuth, deviates from the analogous Thomson relation. Ehrenfest's recent treatment of these phenomena in crystals arrives at the Thomson relations, and thus his treatment, though general, is not sufficiently comprehensive to account for these experimental results.

23. Liquid flow through porous unsaturated mediums. L. A. RICHARDS, *Cornell University.*—When a liquid is absorbed by a porous medium and the medium is unsaturated the pressure within the liquid is less than atmospheric pressure and is determined by the curvature of the air-water interface. Under such circumstances flow of the liquid through the medium is caused by gravity and pressure gradients within the liquid. Analogous to electrical currents in metals, this flow may be expressed in terms of the product of a potential gradient and a

conductivity factor. For the capillary case, however, the conductivity is a function of the potential which in turn is a function of the liquid content of the medium. By means of specially constructed porous cells the conductivity of water through clays, soils and sands has been measured at various potentials. These data furnish a basis for a quantitative study of the motion and equilibrium distribution of water in such mediums.

TUESDAY AFTERNOON AT 2 O'CLOCK

Case School Physics Lecture Room

Annual Business Session of the American Physical Society

TUESDAY AFTERNOON AT 2:30 O'CLOCK

Case School Physics Lecture Room

Paper No. 24 will be read by title.

24. Determination of frequency and damping of resonating circuits. J. TYKOCINSKI-TYKOCINER, *University of Illinois.*—It was found as a further result of studies of thermionic oscillators (Phys. Rev. **33,** 634 (1929); and Univ. of Ill. Eng. Exp. St. Bul. No. 194) that periodic variations of constants of a coupled circuit produce periodic variations of plate and grid current. This property of oscillators was investigated and applied for the determination of frequency and damping of circuits whose location or other conditions do not allow the insertion of a variable condenser, variometer or resonance indicator. The circuit is coupled with a calibrated circuit energized by a thermionic oscillator tube and with an aperiodic circuit, whose reactance or resistance may be varied periodically by means of an electromagnetic tuning fork, buzzer or by superposed a.c. When the oscillator is being tuned, variations of the plate and grid current are produced, which show a periodicity corresponding to that of the tuning fork or a.c. and a transient amplitude passing through two maxima and a sharp minimum placed between them. The *M*-curve of effective current values thus obtained is a curve of derivates of the Bjerknes resonance curve. The minimum coincides with the fundamental frequency. The interval separating the two maxima is proportional to the decrement of the measured circuit. The maxima and minimum of the *M*-curve are audible in a telephone receiver. The complete curve is obtained by thermoelectric or thermionic instruments connected to amplifiers. The method was applied to closed circuits and antennae at frequencies from 100 to 100,000 kc.

25. The amplification of small direct currents. L. A. DUBRIDGE, *Washington University, St. Louis.*—A series of tests has been made by the author, under the supervision of Dr. Hull at the General Electric Laboratories, to investigate the possibilities of using a newly developed four-element thermionic tube, the FP-54 Pliotron, (described by Metcalf and Thompson, Phys. Rev. **36,** 1489 (1930)) in place of an electrometer in the measurements of very small direct currents. Simple circuits of standard types were found suitable and a wide range of sensitivity obtained. (1) With a single-tube circuit, using a Type R galvanometer and an input resistance of 10^{10} ohms, a current sensitivity of 10^{-14} amp/mm is readily obtained. (2) Greater stability is attained by using a balanced two-tube circuit, with which a sensitivity of 10^{-16} amp/mm can be reached. (3) By "floating" the two grids of this circuit and using the "rate of drift" method of measurement, it was found that currents as small as 5×10^{-18} amp could be detected. (4) To enable the output to be read on a microammeter a second stage of amplification was employed. A deflection of 4 micro-amp. was obtained for an input current of 10^{-13} amp. The circuits are all more stable and simpler to operate than an electrometer of equal sensitivity, and the highest attainable sensitivity is greater than for any type of electrometer except the Hoffman.

26. Studies in non-linear circuits. CHAUNCEY GUY SUITS, *General Electric Company, Schenectady.* (*Introduced by A. W. Hull*).—The fundamentally important series inductance, capacitance, resistance circuit

$$L'(i)\frac{di}{dt}+\frac{1}{C(i)}\int idt+iR(i)=f(t), \tag{1}$$

where the parameters are functions of the current, is discussed. The frequent occurrence and great practical importance of circuit elements which depend upon the current are noted. The particular cases of the series and parallel circuit with linear resistance, linear capacitance, and a non-linear iron-core inductance are studied in detail. For the *series circuit* it is shown that the abrupt rise in current with increase in voltage at a certain critical voltage for the circuit may be identified as a quasi-resonance condition, called *non-linear resonance*. The condition for resonance in the linear circuit,

$$-L'\frac{di}{dt}+\frac{1}{C}\int idt, \tag{2}$$

is generalized as

$$-L'(i)\frac{di}{dt}=\frac{1}{C(i)}\int idt \tag{3}$$

for non-linear cases. The relation (3) is satisfied in the steady state *during a portion of each cycle*, wherein the peak current may be calculated from Ohm's law. For the *parallel* circuit *non-linear resonance* similarly obtains, and is associated with a decrease in total effective current with increase in voltage (r.m.s.), a property unique in circuits. The fundamental analogy between the behavior of linear circuits to changing frequency and non-linear circuits to changing voltage follows from the predominating voltage dependence of impedance for the non-linear iron-core inductance. The paper will be accompanied by demonstration apparatus if time permits.

27. The effect of the temperature dependence of the work function on A and b in Richardson's equation. J. A. Becker and W. H. Brattain, *Bell Telephone Laboratories, Inc., New York.*—The most general form of Richardson's equation is

$$i=AT^{-1/2}\epsilon^{\int(L_p/RT^2)dT} \tag{1}$$

where L_p represents the energy added to the system when one mole of electrons is "vaporized" at constant pressure. This equation follows necessarily from the first and second law of thermodynamics and from the generally accepted assumption that the electron vapor behaves like a perfect gas. In order that

$$i=AT^2\epsilon^{-b_0/T} \tag{2}$$

it is *necessary* that

$$L_p=b_0R+5RT/2 \tag{3}$$

and *to assume that b_0 is independent of T.* $5RT/2$ represents the kinetic energy of the electron gas plus external work done per mole at constant pressure. It is generally assumed or deduced that the electrons in the metal receive negligible energy when T is increased. In that case, $L_p-5RT/2$ represents work done per mole against various electrical forces. Call this bR. If bR depends on T, (1) becomes

$$i=AT^2\epsilon^{\int(b/T^2)dT}. \tag{4}$$

If $b=b_0+\alpha T$

$$i=AT^{2+\alpha}\epsilon^{-b_0/T}. \tag{5}$$

If the work function varies linearly with T, we conclude: 1. equation (5) replaces (2) which is invalid; 2. the mean slope of $\log i-2\log T$ vs. $1/T$ is $b_0+\alpha T$ and not b_0; 3. the intercept of this plot is $\log(A\epsilon^{\alpha}T^{\alpha})$ and not $\log A$ or $\log(A\epsilon^{-\alpha})$.

28. Conductivity of oxide cathodes. N. H. Williams and W. S. Huxford, *University of Michigan.*—The conductive properties of oxide coatings used in the equipotential cathode type of radio tube have been investigated. The inner nickel sleeve served as one electrode, the second being a nickel strip in contact with the outer surface of the oxide. Currents through the coating as measured at constant potential vary with the frequency of the applied electromotive force. A decrease in conductivity of about forty percent occurs when the freqeuncy is chang-

ed from 1500 to about 10,000 cycles per second. The decrease starts at lower frequencies for higher values of applied potential. These results indicate a transfer of electrical charges through the coating by ionic conduction, the process being inhibited at the higher frequencies. A method of estimating the relative thermionic activities of core metal and oxide surface is suggested. Fluctuations in the current through the coating were measured on an amplifier tuned to various frequencies from 200 to 40,000 cycles per second. An abnormal increase in "shot" voltage was found for frequencies below 10,000 cycles. This result is believed to confirm the hypothesis that positively charged ions are neutralized in the space charge produced by electrons which are emitted thermionically from the activated surface of the core metal.

29. The electrical polarization of electrets. MAURICE EWING, *Lehigh University.*—The internal electrical polarization of an electret was determined by breaking a piece of the electret along a plane normal to the direction of polarization and measuring the charge per unit area which appeared on the newly-formed surfaces. The polarization for this particular electret was found to be 2.0 ± 0.2 esu/cm^2. The theory of Adams (Frank. Inst. J., **204**, 469 (1927)) seems to require that the polarization in an electret be of the order of 10^5 esu/cm^2.

30. Electrical characteristics of a viscous mineral insulating oil as functions of temperature and frequency. H. H. RACE, *General Electric Co., Schenectady.*—Data recently taken on the dielectric loss and the dielectric constant of good mineral insulating oils lead to the following conclusions: (a) At constant temperature the dielectric constant decreases by only a few percent as the frequency is increased from sixty to two million cycles per second. (b) At constant frequency the dielectric constant decreases with increased temperature and this change appears to be proportional to the decreasing density of the oil. (c) For a given temperature there is a critical frequency such that for all lower frequencies the A.C. loss is independent of the frequency and for all higher frequencies the loss increases with the frequency. Within the first frequency range the mechanism of D.C. conduction and of A.C. loss appear to be the same, and both are probably due to the migration of charged ions or larger particles in the oil. Within the second range, the loss per cycle, (after that resulting from D.C. conduction has been subtracted), shows resonance characteristics as a function of either temperature or frequency. (d) The higher the temperature, the higher the critical frequency below which the A.C. and D.C. losses are the same. Power factors as high as 1% have been observed under conditions for which the loss resulting from conduction would be negligible. These data have been studied from the point of view of Debye's theory of polar molecules, and a qualitative agreement has been found.

31. Dielectric constants of certain organic compounds. W. R. PYLE, *The Ohio State University.*—The dielectric constant of an organic compound is thought to be allied with its other physical properties such as solvent power and molecular complexity. Probably the future will reveal a more definite correlation between the dielectric constant and the other physical properties of a compound. The nulled heterodyne method of measurement of dielectric constants was made possible by the advent of the triode valve and it is employed in this work. For room temperature and at a frequency of 85.8 kilocycles the dielectric constant was determined for each of the following: benzene, carbon tetrachloride, chloroform, cinnamic aldehyde, ethyl ether, methyl cyclohexane, methyl o-nitrobenzoate, nitrobenzene, oxalyl chloride, n-propyl ether, iso-propyl ether, o-xylene, m-xylene and p-xylene. The temperature coefficients of the dielectric constant for ortho-, meta-, and para-xylenes were determined over a range of about 25°C for both the linear formula and Abegg's formula. It seems reasonable to believe that the values of the dielectric constants determined in this work are relatively as accurate as the purity of the organic compounds.

32. Maintaining direction in flight. JAMES D. TEAR, *General Electric Co., Schenectady, N.Y.*—Accelerations due to changes in course cause the aircraft compass to be responsive to the vertical component of the earth's magnetic field and to be misleading as a direction instrument. North courses cannot be flown without other reference means. The potential generated by an electromagnetic compass is a function of the course setting θ, the course error $\Delta\theta$ and the product of angular velocity and speed or the angle of bank ϕ. A gyroscopic device, the sensitivity of which is controlled by the course setting mechanism, supplies a potential proportional

to sin ϕ and cos θ compensating the acceleration error. An additional angular velocity effect independent of course is added. A null effect then requires an angular velocity toward the chosen course proportional to angular displacement, the condition for aperiodic steering. The adequacy of the system for maintaining direction in clouds has been verified in a series of experiments in which the rudder angle was automatically made porportional to the algebraic sum of the potentials in the compass circuit.

33. A method of weather forecasting. R. C. COLWELL, *West Virginia University.*—It has been shown before that when a high pressure area covers both Pittsburgh and Morgantown, the day signal from KDKA is stronger than the night signal, while for a low pressure area, the night signal is the stronger. Hence the ratio of the day to the night energy received from KDKA at Morgantown will give some indication of the atmospheric conditions between the two cities. In this method of forecasting, a fading curve is taken for about one hour before sunset and three hours after sunset. The area is measured with a planimeter and the ratio of the day to night energy is calculated for each day. If this ratio is greater than one, fair weather is indicated; whereas, if the ratio drops to one half, a storm is approaching. In addition to this ratio, barometer readings are taken and wind directions observed. A storm area passing north of Morgantown will cause a low barometer and a south wind. If the storm center passes to the south, the energy ratio from a station to the north is no longer reliable and readings must be taken upon a station to the south.

TUESDAY AFTERNOON AT 2:30 O'CLOCK

Western Reserve Physics Lecture Room

34. Photoelectric properties of composite surfaces at various temperatures and potentials. DIMITER RAMADANOFF, *Cornell University. (Introduced by Ernest Merritt.)*—A large number of experiments were carried out with Ba photoelectric cells to determine the variation of photoelectric current with temperature and plate potential. In all cases the photoelectric current increased greatly at the higher temperatures, and reached maximum at 740°C. At this temperature the thermionic current was limited by space charge. By illuminating the photoelectric cell with interrupted light, the intensity of which was varied sinusoidally, it was possible to measure the photoelectric current with a new method which incorporates the use of a transformer coupled amplifier and a Bedell-Reich stabilized "Oscilloscope." With this apparatus the thermionic current, and sluggish currents which may be due to light in a secondary way, were completely eliminated and only the true photoelectric currents were measured. In this way a curve was obtained which represents the relation of photoelectric current vs. temperature at a constant applied voltage. This curve shows two distinct maxima at 560°C and 740°C the first of which is not observable with a galvanometer if constant illumination is used.

35. Correlating the selective photoelectric effect with the selective transmission of electrons through a cathode surface. A. R. OLPIN, *Bell Telephone Laboratories, Inc.*—The results of Fowler and others with respect to the penetration of α-particles into a model nucleus suggested the possibility of explaining the selective photoelectric effect by the selective transmission of electrons of a definite velocity through the cathode surface. These electrons must be associated with waves of such length that they will form standing waves between abrupt potential discontinuities of like sign on the cathode surface. The existence of such a potential valley may be reasonably postulated, particularly for surfaces consisting of a layer of electronegative atoms or molecules sandwiched between electropositive layers. By interpreting the width of the valley to be the distance between the nuclear boundaries in successive electropositive layers and substituting these for d in the earily derivable equation $\nu_{max.} = n^2h/8md^2$ [or $d = 0.0549\ \lambda_{max.}^{1/2}$ Angstroms, for the case of $n = 1$], an extremely close correlation with experimental facts results. All the observed selective maxima in spectral photoelectric response curves for the hydrides, oxides and sulphides of the alkali metals have been checked by this equation with a higher degree of accuracy than has been obtained by any other theory.

36. Physical detectors of "Mitogenetic Radiation." OTTO GLASSER AND V. B. SEITZ, *Cleveland Clinic Foundation, Cleveland, Ohio.*—Experiments of Alexander Gurwitsch and co-

workers in 1924 showed that some form of radiation from growing and dividing cells of various plants and tissues produced increased mitosis in other cells. Since then this observation has been experimentally substantiated by numerous other workers. An attempt is described to detect and classify these "mitogenetic radiations" by physical means and some results of these experiments are reported.

37. Thermoluminescence excited by exposure to radium. FRANCES G. WICK, *Vassar College.*—The experiments described in this paper were made at the Institute for Radium Research in Vienna and the method of observation is one which has been used there by Dr. Karl Przibram. Calcium sulphate plus manganese and specimens of fluorite were exposed to radium and the thermoluminescence excited by this exposure was measured by heating the specimens in front of a photo-electric cell connected with a Wulf electrometer. Observations were made from the beginning of heating until the light was exhausted. Subjecting the specimens to a pressure of 10,000 Kg/cm^2 either before or after exposure to radium was found to change the intensity of the light emitted. Calcium sulphate plus manganese shows a single maximum of intensity as the temperature rises. The effect of pressure applied either before or after exposure to radium is to diminish the height of this maximum. Powdered fluorite previously heated to remove all natural thermoluminescence, shows, after exposure to radium, a number of sharp maxima due to different rare earth impurities. These maxima are lowered as a result of pressure. A broad diffuse band in the blue upon which the sharp bands are superimposed is made stronger as a result of pressure.

38. Significance of wave-length in color vision. C. A. RINDE, *College of the Pacific.*—Helmholtz and Koenig showed all color sensations to be reproducible by mixing light of three specific wave-lengths. Ladd-Franklin suggested Red and Green, Blue and Yellow as primary; each pair belonging to a single sensitive mechanism. The author's measurements of the retinal areas sensitive to homogeneous light selected from various regions of the grating spectrum indicate that the four areas exist and are independent. The approximate wave-length range to which each is sensitive has been measured, and an additional area sensitive only to the shorter wave-lengths has been found.

39. Appearance of color bands in films of sputtered tin. LESTER I. BOCKSTAHLER AND C. J. OVERBECK, *Northwestern University.* Small circular cathodes of tin are used to sputter films on glass. These films show concentric rings of color similar in appearance to Newton's rings. When viewed with monochromatic light, the rings are alternately light and dark. In white light the films show several cycles of the colors of the visible continuous spectrum. The growth of a set of rings, when viewed with reflected white light, begins with the appearance of a blue center a few seconds after the discharge is started. This center gradually passes through a cycle of colors of increasing wave length until it is red. With the appearance of each new center color all preceding colors move outward and form surrounding bands. The red center then merges into blue and the cycle is repeated. The rate of growth of a set of bands depends on the nature of the gas as well as on its pressure and the current density. Under a given set of conditions the change of color of the center and the addition of another set of color bands takes place with very definite regularity. Work is in progress to determine the chemical nature of these films and the cause of the colors.

40. The transmission of visible light through fog. H. G. HOUGHTON, *Round Hill Research Division, Massachusetts Institute of Technology* (*Introduced by J. A. Stratton*).—Measurements have been made on the transmission of visible light through artificial fog which was produced by condensing low pressure steam. Curves for various densities of fog were plotted and found to have definite maxima at about 4900A. The relation between fog density and the transmission of light was found to be practically linear for all wave-lengths in the visible spectrum. The maxima obtained are not in agreement with the results of other investigators but it is thought that this is due to a difference in the particle size of the fogs. Measurements indicated that the particles of the fogs used were considerably smaller than those of the fogs employed by other experimenters.

41. Theoretical discussion of the transmission of light through fog. J. A. STRATTON AND H. G. HOUGHTON, *Massachusetts Institute of Technology*.—The transmission of light through fog has been studied from a theoretical standpoint in an attempt to explain the experimental results described in another paper. The treatment is based on the work of Debye, Mie, Jobst and others on the pressure of light and on the colors of colloidal solutions. The fog particles are considered to be perfectly dielectric spheres having an index of refraction of 1.33 and a permeability of unity. The coefficient of absorption, which is a function of particle diameter, is obtained by direct summation of Jobst's expression. By proper selection of particle diameter a theoretical curve is arrived at which fits the experimental curve quite closely. This particle size checks the measured value within the accuracy of the measurements. The transmission of light through fog having larger particles may be readily computed in the same manner.

42. Ultraviolet energy radiated by General Electric type S-1 lamps in quartz bulbs. B. T. BARNES, *Nela Park Laboratory, Cleveland*. The energy flux density of the principal ultraviolet lines from general electric S-1 lamps in fused quartz bulbs has been measured. The latter are made somewhat smaller than the Gladd bulbs so that with normal operation the temperature of the mercury pool will be the same in the two cases in spite of the lower absorption of the quartz in the infra-red between 2 and 4μ. The gain in intensity by use of quartz bulbs is even greater than expected. With quartz bulbs the lines at 2650 and 2537A are nearly as strong as those around 3000A.

43. The General Electric photoflash lamp. W. E. FORSYTHE AND M. A. EASLEY, *Nela Park Laboratory, Cleveland*. The bulb of the new photoflash lamp contains about fifty milligrams of aluminum foil that has a surface of about three hundred sixty square centimeters. This lamp can be operated from a one and one half volt storage battery or from a one hundred fifteen volt line. As the lamps are now constructed they start about two hundredths of a second after they are turned on and from the beginning of the flash to the maximum is about sixteen thousandths seconds while the whole flash lasts about six hundredths seconds. The maximum flux amounts to well over one million lumens.

TUESDAY AFTERNOON AT 4 O'CLOCK

Josiah Willard Gibbs Lecture by Professor Edwin B. Wilson of Harvard University

WEDNESDAY MORNING AT 10 O'CLOCK

Case School Physics Lecture Room

Joint Session of the American Physical Society with Section B of the A.A.A.S.

The session on Wednesday morning, December 31st, at ten o'clock will be in charge of the officers of Section B—A.A.A.S. Professor F. K. Richtmyer of Cornell University, Vice-President of Section B will preside.

"Recent Developments in Photoelectricity." Address of the Retiring Vice-President for Section B—A.A.A.S., Charles E. Mendenhall, University of Wisconsin.

SYMPOSIUM ON ACOUSTICS

Invited Papers

44. "Recent Developments in Architectural Acoustics," Paul E. Sabine, Riverbank Laboratories.

45. "Some Physical Characteristics of Speech and Music," Harvey Fletcher, Bell Telephone Laboratories, Inc.

46. "Concerning Some of the Problems Encountered in Recording and Reproducing Photographic Sound Records on Moving Picture Film," Clarence W. Hewlett, General Electric Company.

WEDNESDAY AFTERNOON AT 2 O'CLOCK

Case School Physics Lecture Room

47. Magnetostriction measurements using a heterodyne beat method. A. B. BRYAN AND C. W. HEAPS, *Rice Institute.*—The apparatus previously used in measuring discontinuous changes in length accompanying the Barkhausen effect in nickel has been employed for gross magnetostriction measurements in nickel and iron and in magnetite, hematite and bismuth crystals. Length changes in a direction parallel to the applied magnetic field are measured. The results for nickel and iron are similar to those previously obtained. Magnetite expands for two orientations and contracts for a third and shows no hysteresis. Hematite shows a small expansion for each of two orientations. For bismuth a field of 2160 gauss produces no measurable change in length. It is estimated that $\Delta L/L$ is less than 2.2×10^{-9}. Additional measurements are to be made with larger magnetic fields and higher sensitivity.

48. Variation of magnetic susceptibilities with temperature in Sm^{+++} and Eu^{+++}. AMELIA FRANK, *University of Wisconsin.*—Calculation of susceptibilities in Sm^{+++} and Eu^{+++}, previously made at room temperature only (J. H. Van Vleck and A. Frank, Phys. Rev. **34**, 1494 (1929)) were extended to include values over a temperature range 14°K–1000°K using the theoretical expression previously given (l.c.). The value of the temperature coefficient $(1/\chi)(d\chi/dT)$ at 300°K was found to be -0.00187 for Eu^{+++} and only -0.00032 for Sm^{+++} in contrast with the normal Curie value -0.00333. These values are in satisfactory agreement with existing experimental data. Cabrera finds -0.002 for Eu^{+++} while Freed and other observers report values in the neighborhood of -0.0006 for $Sm.^{+++}$ The coefficient for Sm^{+++} is so abnormally small that accurate percentage agreement cannot be expected. The computed values show that Sm^{+++} should exhibit a curious behavior in that, while at low temperatures the susceptibility decreases quite rapidly with an increase in temperature, a minimum is reached at about 400°K.

49. On the theory of magnetic susceptibilities of salts of the iron group. J. H. VAN VLECK, *University of Wisconsin.* It is well known that the susceptibilities observed for these salts, in marked contrast to those of the rare earths, do not have the theoretical values for free ions, but instead conform to a formula $\chi=N(he/2\pi mc)^2S(S+1)/3kT$ obtained by assuming that only the spin S of the paramagnetic ion contributes freely to the susceptibility. As emphasized by Stoner, (Phil. Mag. 8, 250), this demands that inter-atomic forces quench the magnetic effect of the orbital angular momentum, both in solids and solutions. The present paper aims to show that these forces can really do this. Following Bethe and Kramers, they may be approximately represented by a potential V whose series development usually begins with second order terms $Ax^2+By^2+Cz^2$. If $|(A-B)\bar{x}^2|\gg kT$ etc., or in general if V has no more than rhomboidal symmetry and is large compared to kT, these inter-atomic forces really quench the orbital moment. For the spin to be free, however, one must have $(h\Delta\nu_M)^2/h\Delta\nu_V\ll kT$, where $h\Delta\nu_M$ and $h\Delta\nu_V$ are respectively of the order of magnitude of the multiplet intervals for free ions and of the dissymmetry in V. These conditions require that $h\Delta\nu_V$ likely be of the order 0.1 to 1 volt. This agrees qualitatively with the coloring of iron salts in solution, which indicates that the ion is held in complexes whose binding energy is about 1 volt.

50. Magnetic susceptibilities of some binary alloys. F. L. MEARA, *Ohio State University.*—Gouy's method for measuring susceptibilities has been used to determine the susceptibilities of six series of binary alloys, tin-thallium, cadmium-zinc, antimony-cadmium, antimony-thallium, antimony-lead and antimony-tin. The specimens in the form of small cylindrical rods were made from the purest metals obtainable and were melted either in a vacuum or in an atmosphere of nitrogen. The difference in weight in and outside a magnetic field was determined by means of a Sartorius balance, which under favorable conditions gave the weight to one millionth of a gram. The maximum error did not exceed one percent. Curves showing the relation between susceptibility and concentration indicate the formation of the inter-metallic compound Sb-Cd in the cadmium-antimony series, and Sn-Tl in the tin-thallium series. With the addition of thallium to antimony the diamagnetic susceptibility passes through a minimum when the concentration of antimony is about eighteen percent. The lead antimony series shows

a similar minimum at fifty percent. The susceptibility of the zinc-cadmium series indicates that zinc is slightly soluble in cadmium, and cadmium slightly soluble in zinc, and the remainder of this series of alloys mechanical mixtures.

51. The emission of positive ions from metals. H. B. WAHLIN, *University of Wisconsin.*—The positive ion emission from metals has been investigated by a mass spectrograph method. It has been found that most metals when first heated give off alkaline ions, as has been observed before. In addition, Cr, Mo, W, Ru, Rh, Nb, Ta, when heated to a temperature where vaporization becomes appreciable, give off ions which are singly charged atoms of the electrode material itself. No indications of doubly charged atoms were obtained. Cu, Ag, Au, Zn, Mn, V, Fe, Co, Ni, Pd, Os, Ir, Pt, U, Th, Sb give only alkaline ions. Mn is doubtful. The work is being extended to temperatures above the melting point.

52. Residual ionization in air at new high pressures and its relation to the cosmic penetrating radiation. JAMES W. BROXON, *University of Colorado.*—Residual ionization measurements in air at pressures up to 170 atmospheres were made at 5400 ft. altitude in a spherical chamber of 11-23/32 in. diameter with lead and water shields. Values as low as 1.47 ions/c.c. sec. at 0.83 atmosphere were observed. At pressures above 140 atmospheres ionization-pressure curves obtained with the chamber shielded were parallel to the pressure axis, slopes in this region certainly not exceeding 0.02 ion/cc. sec. atm. Increased shielding decreased the ionization, showing the existence of a penetrating radiation. Observations with water shields showed this radiation to have its origin above the level of the chamber. The calculated absorption coefficients are 0.0127 cm^{-1} lead, and 0.0010 or 0.0028 cm^{-1} water, the latter two values following respectively from the extreme assumptions that the radiation approached entirely from the vertical direction, or uniformly from all directions above the horizontal. If the ionization is considered to be due entirely to recoil electrons excited in the walls of the chamber, the pressure-ionization relation may be explained; and if the Compton theory is used, the absorption coefficient of the initial penetrating radiation as calculated from the observed range of the recoil electrons is found to be 0.0025 cm^{-1} water.

53. The effect of hydrogen upon the intensities of the spectra of zinc, cadmium and mercury. J. G. BLACK AND W. G. NASH, *University of Kentucky.*—When hydrogen is mixed with zinc vapor in a low voltage arc, some of the zinc lines change their intensities markedly. (Phys. Rev. **34,** 1138, (1929)). Recent experiments with the related elements, cadmium and mercury, show similar changes. Hydrogen increases the number of transitions to the 2^3P_{012} configuration of all three elements and greatly reduces the number of transitions from the 2^3P_1 state by radiation. The configuration energy is approximately 4.7 volts in mercury, 4 volts in zinc, and 3.78 volts in cadmium. Hg′ has more than enough energy to dissociate hydrogen. Zn′ has almost exactly enough, which fact may account for the total absence of the 3075.8 line. Cd′ does not have enough energy and probably loses its total energy to tube walls and electrodes after it has been made metastable by hydrogen impacts. An alternative explanation of the resonance quenchings is that they are due to the formation of metallic hydrides. It appears that the absence of a Raie Ultime does not insure the absence of an element in chemical spectroscopic analysis when hydrogen is present.

54. The ionization of hydrogen by positive ion impacts. MASON E. HUFFORD, *Indiana University.*—Positive ions of K, Na, Li and H have been accelerated between a filament and an earthed nickel cathode in an atmosphere of pure hydrogen. The cathode was surrounded by a second nickel screen and this in turn was enclosed by a similar screen in contact with the walls of the ionization tube. Ions were accelerated by potentials varying from zero to 2000 volts and retarded beyond the cathode by a potential 7.5 volts more than the accelerating potential. Current-accelerating potential curves show that the relation between ionization current and potential with K-ions is about linear. Increases can well be explained by the action of electrons from the cathode. With other ions the increase of current is much greater. With low pressures the increase in current is such as to indicate ionization by positive ions. At higher pressures distinct critical potentials are shown at voltages about 200 volts below that at which an arc is established.

55. On the fraction of current carried by electrons at the cathode of a mercury arc. K. T. COMPTON, *Massachusetts Institute of Technology.*—Ever since Schottky first pointed out that studies of heat balance afford a possibility of estimating what fraction of the current at arc cathodes is carried by escaping electrons, attempts have been made to do this in the hope of thereby testing theories of the arc. Such work has heretofore indicated that not much more than half this current is carried by electrons,—a conclusion which is difficult to reconcile with any electron emission theory of the arc cathode because of the impossibility of accounting for a number of positive ions produced by an approximately equal number of electrons which had fallen through a cathode drop amounting to not more than one minimum ionizing potential. Revised estimates are now based on measurements of cathode drop and new considerations involving accommodation coefficients and the destination of electronic energy near the cathode. The conclusion is now reached that between 80% and 100% of the current of the cathode is carried by electrons. Thus it can no longer be said that arc theories based on electron emission from the cathode are disproved by measurements of heat balance.

56. Study of the afterglow in mercury vapor. HAROLD W. WEBB AND DAVID SINCLAIR, *Columbia University.*—The intensity of the afterglow in mercury vapor was studied in a side tube leading from a mercury arc as a function of vapor pressure, concentrations of ions and electrons and electron temperature. The intensity was found to vary roughly as the fourth power of the vapor pressure. Except at very low concentrations it was closely proportional to the first power of the electron concentration. With vapor pressure and concentration held constant, the intensity increased very rapidly with increase in electron temperature, changing by a factor of 2500 as the temperature increased from 1300° to 5600°K. This change is too large to be explained by the theory of the simple recombination process. The results are well expressed in the form, that the intensity varies directly as the square of the total number of electrons and inversely as the number of electrons having energies greater than 1.2 volt. This suggests that we have a recombination process producing the afterglow, which takes place in two stages of which the second is responsible for the emission of the series lines, and that the effect of the fast electrons is to reionize from the first stage.

57. Problems in the design of a tube to withstand millions of volts. WILLARD H. BENNETT, *California Institute of Technology.*—It appears improbable that further increases in potential which can be produced in high voltage tubes can be hoped for until the mechanisms, themselves, of the causes of puncture have been carefully studied. A study of corona discharge over glass led to the conclusion that for further increases of potential, the potential must be generated in vacuum, and that the field must be roughly normal to the glass wall of the tube. The greatest difficulty in obtaining higher potentials in tubes is due to auto-electronic emission from electrode surfaces. A study of emission from unconditioned metal surfaces of radii of curvature large compared to the distance between the surfaces showed that loose microscopic particles adhering to the cathode can give emission indistinguishable from the emission following the usual breakdown. The metal used as anode was found to determine largely or entirely the field-current characteristics.

58. Experiments with high-voltage tubes. M. A. TUVE, L. R. HAFSTAD, AND O. DAHL, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—Measurements have been obtained on the artificial β and γ-rays produced by the high-voltage cascade-tubes and Tesla coils previously described in the Physical Review. The $H\rho$ values of the fastest β-rays, measured by their deflection in a calibrated mangetic field, correspond in voltage-equivalents, using the standard β-ray tables, to the peak voltages applied to the tubes, measured as before by the capacity-potentiometer method. Using a Geiger-Müller tube-counter shielded by six inches of lead, the relative γ-ray intensities from the tubes have been measured through 1, 2, and 3 inches of lead. With the tube operating at about 1,300 kilovolts, the absorption coefficient after filtering through 1 inch of lead is the same (0.47) as that for the γ-rays from radium in equilibrium measured under the same conditions with the same instrument. These β and γ-ray measurements incidentally constitute a verification also of previous voltage-measurements. "Heat working" of the Pyrex, as previously described, has removed the voltage-limitation to such an extent that tubes have operated satisfactorily up to approximately 2,000 kilovolts, this limit (above ground) being set by corona or sparkover to the grounded oil-tank. Experiments are in progress on high-speed protons.

WEDNESDAY AFTERNOON AT 2 O'CLOCK

Western Reserve Physics Lecture Room

59. Multiplet separations and Zeeman effects. J. B. GREEN, *Ohio State University.*—The methods developed by Houston and Goudsmit are applied to the spectra of tin, lead, and antimony. Using the spectroscopic values of the multiplet separations it has been possible to determine the g-values for the configuration p^2 of Sn I and Pb I, and for the configuration ^3Ps of Sb, in very satisfactory agreement with the experimental values of Green and Loring, and Back for these elements. Further agreement is found in the case of the ^3P and ^1P of Sn III. The multiplet separations and g-values calculated on Houston's theory adequately explain the anomalies found by Green and Loring in this spectrum.

60. Photometric study of the appearance of spectral lines in a condensed spark. H. V. KNORR, *Antioch College.*—The time interval between the appearance of spectral lines in a condensed spark has been studied by means of a Kerr cell used as an electro-optical shutter. Since there appears to be some question about the meaning of the time intervals measured in this way, photometric observations have been made on the rate of increase in the intensities of such lines. From the rate of increase of the intensity for a particular line, it is possible to find by extrapolation the time at which the intensity is zero, that is, the time of its first appearance. The results obtained by this method are compared with the results obtained by the visual method. Observations were made on the arc lines $2^3P_{012}-2^3S_1$ of zinc and for five air lines appearing in the zinc spark. These three zinc lines appear at nearly the same time. The five air lines also appear at nearly the same time but definitely at a time earlier than the zinc lines. These results are not in agreement with the results obtained by the visual method. The explanation of this discrepancy may be found in the failure of the visual method to take proper account of the threshold of visibility. These results indicate that neither of these methods give data on the life time of the zinc atoms in the excited state but only data on the characteristics of the spark discharge.

61. Spectra emitted in the initial stages of condensed discharges. J. W. BEAMS, *University of Virginia.*—Certain improvements in the Kerr Cell method (Phys. Rev. **24,** 35, (1930)), (Program O.S.A. Oct. 31, 1930) have made it possible to study the times of appearance of spectrum lines in condensed discharges as a function of pressure of the gas. In mercury vapor $5461(2^3P_1-2^3S)$ was followed very closely (within less than the limit of precision at pressures above 10 cm) by $4358(2^3P_2-2^3S)$ while $5791(2^1P-3^1D)$ appeared somewhat later. As the vapor pressure of the mercury was increased the time between the appearance of 5461 and 5791 decreased. In a discharge in air 5001 N II $(1^3D'_{1,2}-1^3F'_{2,3})$ appeared first. As the pressure was lowered from one atmosphere the time between the appearance of 5001 and 4631, 4643 N II $(1^3P_2'-2^3P_{2,1})$ was decreased while a slight increase was noted in the time between the appearance of 5001 and the group 5680, 5676, 5667, N II $(1^3P'_{2,0,1}-1^3D'_{2,1,2})$. In a mixture of equal amounts of air and helium the time between the appearance of 5001 N II and 5876 (2^3P-3^3D) increased with lowering of pressure. The results probably indicate that some of the above levels are excited in part at least by secondary processes.

62. The sixth spectrum of arsenic. D. BORG, *Upsala University,* AND J. E. MACK, *University of Wisconsin.*—The lines of the transition $3d^94_s \leftarrow 3d^94_p$ have been indentified in As VI. In all respects the spectrum agrees with the expectations from extrapolation of the sequence Ni I–Ge V, unlike the As VI classification proposed by P. Pattabhiramiah and A. S. Rao (Zeits. f. Physik **53,** 587, 1929), in which those authors point out anomalies.

63. Heterochromatic photographic photometry in the Schumann region. GEORGE R. HARRISON AND PHILIP A. LEIGHTON, *Massachusetts Institute of Technology and Stanford University.*—The spectral energy response of several of the fluorescent materials ordinarily used for coating photographic emulsions when used in vacuum spectroscopy has been investigated in the ultraviolet between 4000 and 2300A, and in certain easily reproducible cases the number of fluorescent quanta has been found strictly proportional to the number of incident quanta throughout this range. This fact, taken with the uniformity of contrast previously found under

similar conditions (Jour. Opt. Soc. America **20,** p. 313, 1930) appears to furnish a general method of photographic photometry which can be used throughout the extreme ultraviolet, where the sensitivity of most spectral apparatus is too low to permit the use of thermopiles for plate standardization. The method is now being checked directly with fluorite apparatus in the Schumann region, and is being applied in a 21 ft. vacuum spectrograph to the determination of electronic transition probabilities in multiply ionized atoms of the first long period.

64. Intermittent exposure in photographic spectrophotometry over wide intensity ranges. BRIAN O'BRIEN AND E. DICKERMAN O'BRIEN, *Institute of Optics, University of Rochester, N. Y.* —Previous work on the compensation of reciprocity failure in photographic spectrophotometry by intermittency failure imposed on the light beam of higher intensity by interrupted exposure (Phys. Rev. **33,** p. 640 (1929)) has been extended using sector discs with aperture ratio as low as 1/1200, using a mercury arc as source mounted on a carriage with range of movement of 50 meters for varying intensity. Emission of the arc was held constant within ½% (measured radiometrically) by controlled ventilation and electrical input. Errors in measurement of sector apertures and exposure timing were less than ½%. Densities were measured with a thermoelectric microdensitometer. For intensities in ratio 1200:1 and sector disc opening 1/1200 running 28 flashes per sec., and comparing adjacent areas, the difference in density produced by continuous low intensity and interrupted high intensity (for $It = \text{const}$) on Eastman Process plates developed to high gamma was less than 0.01 for all densities from threshold to 1.0 for all wavelengths from 4358A to 2300A for intensities from approximately optimal to 10^{-4} this value. For $\lambda < 2800$A correction was made for atmospheric absorption as measured by Dawson, Granath, & Hulburt (Phys. Rev. **34,** p. 136 (1929)). Reciprocity and intermittency failure separately determined by continuous exposure of same total energy to the higher intensity were as great as 0.20 density units for intensity ratio 10^3.

65. Band spectrum of sulphur. PAUL HUBER, *Ohio State University.*—The band spectrum of S_2 has been investigated in both emission and absorption. An under-water spark was used as a source for the light absorbed by the vapor in a heated tube, while Geissler tubes were used for the emission spectra. The effect of predissociation is especially evident in emission, the $n^1 \rightarrow 0$ progression suddenly breaking off after the 8-0 band, (λ2828), as reported by Von Icdekinge. The heat of dissociation of normal S_2 is therefore reduced to less than 4.39 volts, as compared with 4.9 volts given by the International Critical Tables. No improvement could be made in the accuracy of the heat of dissociation of excited S_2, because of the extreme irregularities in intensity in emission. Five emission bands lying between λ2828 and λ2980 have been photographed at high dispersion using the second order of a 21-foot grating. The fine structure analysis of these bands is now in progress.

66. Distribution of intensity within the β and γ band systems of nitric oxide. OLIVER R. WULF AND ERNEST J. JONES, *Bureau of Chemistry and Soils, Washington, D. C.*—Variations in the distribution of intensity within the β and γ bands of nitric oxide have been observed when the products from an oxygen discharge tube are allowed to interact with the products from an active nitrogen tube. In this connection attention is called to an abnormal excitation of the γ bands of nictric oxide as they are emitted from an ordinary high current atmospheric pressure arc. The character of the intensity distribution suggests that the excitation arises as a chemiluminescent phenomenon, the energy of excitation being derived from energy made available in reaction. There appears to be evidence for reaction involving metastable nitrogen molecule. If this is the case it illustrates the chemical reactivity in the homogeneous gas phase of one state of the neutral nitrogen molecule. The conditions leading to the alterations in intensity distribution within the band systems mentioned above suggest that the excitation of band spectra is apt to depend on chemiluminescent processes and that the intensity distribution will, therefore, frequently be abnormal.

67. CO bands in the region λ2220 to λ3300. HAROLD P. KNAUSS, *Ohio State University.*—Microphotometer records covering the region from 2200 to 3300A were made of CO band spectra obtained in the electrodeless ring discharge (Knauss and Cotton, Phys. Rev. **36, 1099,** (1930)) and wave lengths were measured. Unidentified bands at wave lengths 2925, 3028, 3138, and 3253A were identified as belonging to a new system, corresponding to transitions from

$C(^1\Sigma)$ to $a'(^3\Sigma)$. According to values for the known energy levels of the CO molecule quoted by Estey (Phys. Rev. **35**, 309 (1930)), the equation for the new system should be

$$\nu = 34160 - (1173n'' - 9n''^2).$$

Comparison between the observed wave lengths and those predicted from this formula is made in the following table.

Transition	ν(Calc.)	λ(Calc.)	λ(Obs.)
0–0	34160	2926.5	2925
0–1	32996	3029.8	3028
0–2	31850	3138.8	3138
0–3	30722	3254.1	3253

68. Infra-red absorption bands of slightly asymmetric molecules. HAROLD H. NIELSEN, *Ohio State University.*—A set of theoretical curves (as yet unpublished) showing the properties of infra-red bands of completely asymmetric molecules have been made by D. M. Dennison. As a complement to these, calculations have been made for molecules of only slight asymmetry. A_x, A_y and A_z have been chosen the three principal moments of inertia of the molecule, where $A_x < A_y < A_z$. Diagrams have been prepared of positions of lines and their respective intensities, determined fron quantum mechanical solutions of asymmetric rotators, where the parameter $\rho = A_x/A_y$ varies by steps of 0.01 within the limits $\rho = 0$ and $\rho = 0.1$. Direct application of these will be made on the spectrum of Formaldehyde (H_2CO) now under observation.

69. Infra-red absorption of formaldehyde vapor. JOHN R. PATTY AND HAROLD H. NIELSEN, *Ohio State University.*—Measurements of Formaldehyde vapor (H_2CO) have been made with a Hilger infra red spectrometer of the Wadsworth type from the visible to 7.0μ. The spectrometer is equipped with a rock salt prism and a Coblentz thermopile, and is used in conjunction with a Moll thermal relay and a Leeds and Northrup high sensitivity moving coil galvanometer. The bands reported by Salant and West have been confirmed and in addition a band of relatively strong intensity was found at 4.7μ and another faint band at 2.3μ. The bands listed in order of their intensities are, 4.7μ, 3.38μ, 1.8μ, 1.4μ, 2.3μ, and 1.25μ. Another faint maximum was found at 1.9μ, but it is believed that this may be a part of the 1.8μ band reported by Salant and West. The band at 3.38μ has been resolved into fine line structure by the aid of a prism-echelette grating of the Sleator type. The general characteristics of the band are P, Q and R branches of which the Q branch is relatively weak and a fine line structure of 4.5 cm^{-1}.

70. The spectrum of strontium and barium hydride. W. R. FREDRICKSON AND A. L. WARNTZ, *Syracuse University.*—Bands ascribed to the hydrides of the elements strontium and barium, as obtained by an arc between iron and the element in an atmosphere of hydrogen, lie in the far red end of the spectrum, degrade to the violet, but show no similarity. The strontium bands lie in the region λ7500 to λ6800 with double heads at 7350, 7323 and 7020, 6985, the latter being the more intense. At the far red end of spectrum there is a peculiar intensity distribution, showing no sharp heads and with large open spaces in the fine structure. At high dispersion the 7020 band shows four strong branches, indicating a $^2\Sigma - ^2\Sigma$ transition. The barium band lies in the region λ6925 to λ6380 and is a $\Pi^2 - ^2\Sigma$ band, showing satellite series which are relatively strong in comparison with the customary P, Q, R series.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session in the Case School Physics Lecture Room after the completion of the regular program for the session.

71. Comparison of x-ray diffraction intensities in liquid long chain compounds with intensities from computations based on a structure factor. G. W. STEWART AND ROSS D. SPANG-

LER, *The State University of Iowa.*—Quantitative determination of intensities of x-rays scattered from some liquid long-chain compounds are carried out and the results compared with values obtained from experiments. The determinations are based upon the idea of molecular grouping in liquids. A structure factor of the molecules is used to obtain the intensities. Computations are carried out and comparisons made in the case of eleven normal alcohols and twenty-two octyl alcohols. In the majority of cases, the agreement between experimental and computed values is very good, in a few it is fair, and, in a case or two it is poor. On the whole, the results give convincing evidence in favor of molecular grouping in liquids.

72. Useful accessories for the Siegbahn x-ray vacuum spectrograph. F. K. RICHTMYER, *Cornell University.*—To avoid registration on the photographic plate of minute surface imperfections of the crystal, it has been usual to rotate the crystal, by steps of a few minutes of arc, through a degree or so during an exposure. A device is described, consisting of a telechron motor and reducing gear, for producing continuous, slow oscillations of the crystal through any desired small angular amplitude. To facilitate rapid identification of spectral lines by comparison with some known line, a special plate holder has been devised by means of which a linear scale may be printed on the photographic plate above the x-ray spectrum. The background due to scattered radiation from the crystal reaching the photographic plate frequently covers up faint lines or makes their measurement difficult. When one is interested in a narrow spectral region the intensity of this background can be materially reduced by placing a wedge a millimeter or two in front of the crystal, somewhat after the manner of the Seemann spectrograph. However, inequality of the x-ray brightness of the focal spot then necessitates that the (spiral) filament should be slowly rotated during exposure.

73. Formation of photographic images on cathodes of alkali metal photoelectric cells. A. R. OLPIN AND G. R. STILWELL, *Bell Telephone Laboratories, Incorporated.*—A method of forming both negative and positive photographic images on the cathodes of potassium and sodium photoelectric cells in vacuum is described. These images are sharp and clear in every detail and can be permanently "fixed" by proper treatment. Among the materials which have been successfully used in treating the exposed surfaces to bring out these images are sulphur vapor, air, oxygen and hydrogen in the ratio of 9 to 1, hydrofluoric acid and bromine. During the time the image is forming, the photoelectric sensitivity of the illuminated portions decreases approximately 30 per cent. After the image is fixed as a permanent record there is little difference between the sensitivity of the cathode area bearing the image and neighboring areas. Photographs of photoelectric cells are shown in which such photographic images are plainly visible.

74. The emission of positive ions from thoriated tungsten. H. B. WAHLIN, *University of Wisconsin* An investigation of the emission of positive ions from thoriated tungsten shows that when heated to a temperature above 2000°C three types of ions are given off: a W ion of mass 184, a second ion of mass 232, and a heavier ion of mass 247 ± 1. This heavy ion may be a mononitride or a monoxide of throium. That it cannot be WO_4 is shown by the fact that it does not disappear when the wire is heated in an atmosphere of hydrogen. Outgassing of the wire at an estimated temperature of 1200°C for 100 hours in a vacuum of 10^{-6} mm does not cause the ion to disappear. Varying the gas pressure in the positive ray chamber from 10^{-6} mm to 10^{-5} mm has no effect on the ion. Prolonged heating at a temperature above 2000°C will cause the 247 ion to decrease with respect to the 232 ion which is assumed to be thorium. Neither the 232 ion nor the 247 ion appeared when unthoriated tungsten or thorium metal were used. An x-ray investigation of the L region of samples of thoria ores has so far failed to give any indication that the heavy ion may be of an elementary nature.

75. The dielectric constant of air at high pressures. JAMES W. BROXON, *University of Colorado.*—Measurements of the dielectric constant of dry air at zero frequency were made by a balance method, using a quadrant electrometer as an indicator. The dielectric constant was found to increase linearly with the pressure at the rate of 555×10^{-6} per atmosphere at 18°C., up to 170 atmospheres. The Clausius-Mossotti function passes through a minimum in this region.

76. A lens for use with the concave grating. J. B. GREEN, *Ohio State University.*—When the slit for a concave grating is placed on the circle of half the radius of curvature of the grating the focal plane is found to be on that circle for a vertical astigmatic image. In general, regardless of the position of the slit, the other focus is found to be hyperbola. This method of calculation yields a very simple result useful for the calculation of the lengths of the astigmatic images. For the study of individual lines a sphero-cylindrical lens may be used to correct this astigmatism with a resultant increase in the intensity available, and at the same time, a possibility of markedly increasing the dispersion. A preliminary study of several lines with such a lens has yielded promising results.